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PATENT APPLICATION

PIEZOELECTRIC PLATEN DESIGN FOR IMPROVING PERFORMANCE IN CMP APPLICATIONS

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CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to the following applications: (1) U.S. Patent Application No. __________ (Attorney Docket No. LAM2P220A), filed December 21, 2000, and entitled "Platen Design for Improving Edge Performance in CMP Applications"; and (2) U.S. Patent Application No. __________ (Attorney Docket No. LAM2P220B), filed December 21, 2000, and entitled "Pressurized Membrane Platen Design for Improving Performance in CMP Applications." Each of these related application is incorporated herein be reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to chemical mechanical polishing apparatuses, and more particularly to platen designs using piezoelectric elements for improved performance in chemical mechanical polishing applications.

2. Description of the Related Art

In the fabrication of semiconductor devices, there is a need to perform Chemical Mechanical Polishing (CMP) operations, including polishing, buffing and wafer cleaning. Typically, integrated circuit devices are in the form of multi-level structures. At the substrate level, transistor devices having diffusion regions are formed. In subsequent levels, interconnect metallization lines are patterned and electrically connected to the transistor devices to define the desired functional device. Patterned conductive layers are insulated from other conductive layers by dielectric materials, such as silicon dioxide. As more metallization levels and associated dielectric layers are formed, the need to planarize the dielectric material increases. Without planarization, fabrication of additional metallization layers becomes substantially more difficult due to the higher variations in the surface topography. In other applications, metallization line patterns are formed in the dielectric material, and then metal CMP operations are performed to remove excess metallization.

In the prior art, CMP systems typically implement belt, orbital, or brush stations in which belts, pads, or brushes are used to scrub, buff, and polish one or both sides of a wafer. Slurry is used to facilitate and enhance the CMP operation. Slurry is most usually introduced onto a moving preparation surface, *e.g.*, belt, pad, brush, and the like, and distributed over the preparation surface as well as the surface of the semiconductor wafer being buffed, polished, or otherwise prepared by the CMP process. The distribution is generally accomplished by a combination of the movement of the preparation surface, the

movement of the semiconductor wafer and the friction created between the semiconductor wafer and the preparation surface.

Figure 1 illustrates an exemplary prior art CMP system 10. The CMP system 10 in Figure 1 is a belt-type system, so designated because the preparation surface is an endless belt 18 mounted on two drums 24 which drive the belt 18 in a rotational motion as indicated by belt rotation directional arrows 26. A wafer 12 is mounted on a wafer head 14, which is rotated in direction 16. The rotating wafer 12 is then applied against the rotating belt 18 with a force F to accomplish a CMP process. Some CMP processes require significant force F to be applied. A platen 22 is provided to stabilize the belt 18 and to provide a solid surface onto which to apply the wafer 12. Slurry 28 composing of an aqueous solution such as NH_4OH or DI containing dispersed abrasive particles is introduced upstream of the wafer 12. The process of scrubbing, buffing and polishing of the surface of the wafer is achieved by using an endless polishing pad glued to belt 18. Typically, the polishing pad is composed of porous or fibrous materials and lacks fix abrasives.

Figure 2 is a detailed view of a conventional wafer head and platen configuration 30. The wafer head and platen configuration 30 includes the wafer head 14 and the platen 22 positioned below the wafer head 14. The wafer head 14 includes a fixed retaining ring 32 that holds the wafer 12 in position below the wafer head 14. Between the wafer head 14 and the platen 22 is the polishing pad and belt 18. The polishing platen 22 is closely spaced from a polishing pad or belt 18 with a very thin air space, referred to as an "air bearing", being defined between the platen 22 and the polishing pad 18. The air bearing

between the platen 22 and the pad 18 has been conventionally used in an attempt to create a uniform polishing of the surface.

To maintain the air bearing, air source holes generally are formed in the platen 22 and are arranged in concentric ring patterns from the center of the platen 22 to the outer edge of the platen 22. Each ring establishes an air delivery zone where air from an air source is directed through the holes during polishing, thus establishing the air bearing. Air is exhausted past the platen edge.

With multiple air delivery zones, the air distribution profile of the air bearing can be varied radially as necessary to achieve optimal polishing by vary the polishing rate in each zone. Unfortunately, the distribution profiles of the zones are not completely independent of each other. This complicates establishing different distribution profiles for different zones.

Moreover, the air bearing is very sensitive to conditions. For example, the pressure of the air bearing varies with the gap between the pad 18 and the platen 22. Thus, if the pad 18 is pushed toward the platen 22 in one area, the pressure of all areas of the air bearing are affected, thus adding unwanted complexity to the CMP process.

In view of the foregoing, there is a need for a method that establishes greater independence of the air distribution profiles, zone to zone, thereby facilitating establishing a polishing rate in each zone independently of the other zones and, hence, improving manufacturing flexibility and functionality.

SUMMARY OF THE INVENTION

Broadly speaking, the present invention fills these needs by providing improved performance in a CMP process using piezoelectric elements as a replacement for a platen air bearing. In one embodiment, a platen for improving performance in CMP applications is disclosed. The platen includes a plurality of piezoelectric elements disposed above the platen. In operation, the piezoelectric elements are used to exert force on the polishing belt during a CMP process. In this manner, zonal control is provided during the CMP process.

In another embodiment, a system for improving performance in CMP applications is disclosed. The system includes a wafer head capable of carrying a wafer, and a polishing belt positioned below the wafer head. Further included in the system is a platen having piezoelectric elements positioned below the polishing belt. The piezoelectric elements are capable of exerting force on the polishing belt.

A method for improving performance in CMP applications is disclosed in yet another embodiment of the present invention. Initially, a platen is provided having piezoelectric elements positioned below a polishing belt, which is disposed above the platen. The piezoelectric elements of the platen are capable of exerting force on the polishing belt. A wafer is then applied to the polishing belt, and the polishing belt is stabilized using the platen, where the piezoelectric elements on the platen apply specific forces to the polishing belt.

Advantageously, the piezoelectric elements of the embodiments of the present invention improve performance during a CMP process by providing increased zonal

control to the pressurized membrane. Further, unlike a conventional air bearing, the piezoelectric elements of the embodiments of the present invention greatly reduces the amount of air needed during the CMP process.

Moreover, a CMP process using the piezoelectric elements of the present invention is not as sensitive to conditions as conventional CMP processes utilizing air bearings. Unlike air bearings, the force exerted by the piezoelectric elements of the present invention does not experience as great a variance as experienced by air bearings when the gap between the polishing pad and the platen varies. Thus, if the polishing pad is pushed toward the platen in one area, the force exerted on the polishing belt by other piezoelectric elements is not as affected as other areas would be when utilizing an air bearing.

Other aspects and advantages of the invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

Figure 1 illustrates an exemplary prior art CMP system;

Figure 2 is a detailed view of a conventional wafer head and platen configuration;

Figure 3 is a diagram showing a platen configuration, in accordance with an embodiment of the present invention;

Figure 4 is a detailed diagram showing a platen configuration, in accordance with an embodiment of the present invention;

Figure 5 is a diagram showing a platen configuration having varied annular bladders, in accordance with an embodiment of the present invention;

Figure 6A is a top view of an annular bladder configuration, in accordance with an embodiment of the present invention;

Figure 6B is a top view showing an annular bladder configuration, in accordance with an embodiment of the present invention;

Figure 7 is a diagram showing a platen configuration, in accordance with an embodiment of the present invention;

Figure 8 is a top view of a piezoelectric element configuration, in accordance with an embodiment of the present invention; and

Figure 9 is an illustration showing a CMP system, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An invention is disclosed for improved performance in a CMP process using piezoelectric elements as replacement for a platen air bearing. The present invention provides piezoelectric elements atop a platen, which provide zonal control during the CMP process. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps have not been described in detail in order not to unnecessarily obscure the present invention.

Figures 1-2 have been described in terms of the prior art. Figure 3 is a diagram showing a platen configuration 300, in accordance with an embodiment of the present invention. Prior to describing a platen configuration having piezoelectric elements, another embodiment of the present invention, which utilizes annular bladders will be described. The platen configuration having piezoelectric elements will be described later with respect to Figures 7-9.

The platen configuration 300 of Figure 3 includes a wafer head 302 having a retaining ring 304 and a wafer 306 positioned below the wafer head 302. The platen configuration 300 also includes a platen 308 disposed below a polishing belt 310. The platen 308 includes a pressurized membrane 312 pressurized via annular bladders 314.

During operation the platen 308 is placed against the polishing pad or belt 310 that polishes the surface of the wafer 306. To promote polishing uniformity, each bladder 314 may be individually pressurized via an air source. Advantageously, the annular

bladders 314 improve performance in the CMP process by providing increased zonal control to the pressurized membrane 312. Unlike a conventional air bearing, the pressurized membrane 312 of the embodiments of the present invention greatly reduces the amount of air needed during the CMP process.

Moreover, a CMP process using the pressurized membrane 312 of the present invention is not as sensitive to conditions as conventional CMP processes utilizing air bearings. Unlike air bearings, the pressure of the pressurized membrane 312 of the present invention does not experience as great a variance as experienced by air bearings when the gap between the polishing pad 310 and the platen 308 varies. Thus, if the polishing pad 310 is pushed toward the platen 308 in one area, the pressure in other areas of the pressurized membrane 312 are not as affected as other areas would be when utilizing an air bearing.

Figure 4 is a detailed diagram showing a platen configuration 400, in accordance with an embodiment of the present invention. The platen configuration 400 shows a polishing belt 310 positioned above a platen 308 having a pressurized membrane 312 pressurized by annular bladders 314. As shown in Figure 4, each annular bladder 314 comprises a thin tubular material 402. In one embodiment, the tubular material 402 of each annular bladder 314 is pressurized via air. However, it should be noted that the tubular material 402 can be pressurized utilizing any other means capable of pressurizing an annular bladder 314, such as a fluid, as will be apparent to those skilled in the art.

The pressurized membrane 312 preferably comprises a smooth, flexible material. Suitable materials include; polyurethane, silicon, thin metals (e.g., stainless steel), peek, and Teflon. As previously mentioned, the annular bladders 314 provide increased zonal

control during a CMP process. To further increase zonal control, the size of the annular bladders 314 within the pressurized membrane 312 can be varied, as described in greater detail subsequently.

Figure 5 is a diagram showing a platen configuration 500 having varied annular bladders, in accordance with an embodiment of the present invention. The platen configuration 500 includes a platen 308 having a pressurized membrane 312 pressurized via annular bladders 314. As shown in Figure 5, the platen configuration 500 includes annular bladders 314 having varying sizes.

More specifically, the annular bladders 314 decrease in size as the annular bladders 314 approach the edge of the platen 308. Generally, during a CMP process, more difficulty occurs within about 10-15 mm of the wafer edge. For this reason, one embodiment of the present invention increases resolution near the wafer edge by decreasing the size of the annular bladders 314 near the edge of the platen 308. Similarly, since the center of the wafer typically requires less resolution, the central annular bladders 314 often are larger than those at the edge of the platen 308.

Figure 6A is a top view of an annular bladder configuration 600a in accordance with an embodiment of the present invention. The annular bladder configuration 600a includes concentric annular bladders 314a. In one embodiment, each concentric annular bladder 314a of the annular bladder configuration 600a forms a complete circle about the center of the platen. In this manner each annular bladder 314a can be individually pressurized to provide zonal control during the CMP process. To further increase zonal control during the CMP process, the length of each annular bladder can be reduced, as discussed next with reference to Figure 6B.

Figure 6B is a top view showing an annular bladder configuration 600b in accordance with an embodiment of the present invention. The annular bladder configuration 600b includes concentric annular bladders 314b. Unlike the embodiment of Figure 6A, each concentric annular bladder 314b of the annular bladder configuration 600b does not form a complete circle about the center of the platen. Each concentric annular bladder 314b of the annular bladder configuration 600b varies in size depending on a particular annular bladder's 314 proximity to the edge of the platen.

As mentioned above, during a CMP process, more difficulty generally occurs within about 10-15 mm of the wafer edge. For this reason, one embodiment of the present invention increases resolution near the wafer edge by decreasing the size of the annular bladders 314b near the edge of the platen. Similarly, since the center of the wafer typically requires less resolution, the central annular bladders 314b often are larger than those at the edge of the platen.

Advantageously, embodiments of the present invention improve performance in CMP applications by providing increased zonal control via a membrane pressurized using internal annular bladders. Other embodiments of the present invention also improve performance in CMP applications by providing increased zonal control via piezoelectric transducers.

Many polymers, ceramics, and molecules such as water are permanently polarized, having some parts of the molecule positively charged, while other parts of the molecule are negatively charged. When an electric field is applied to these materials, these polarized molecules align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. Furthermore, a

permanently-polarized material such as quartz (SiO_2) or barium titanate ($BaTiO_3$) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. These materials are piezoelectric, and this phenomenon is known as the piezoelectric effect. Conversely, an applied electric field can cause a piezoelectric material to change dimensions. This phenomenon is known as electrostriction, or the reverse piezoelectric effect.

Hence, one embodiment of the present invention utilizes piezoelectric materials to provide zonal control during a CMP process. Figure 7 is a diagram showing a platen configuration 700, in accordance with an embodiment of the present invention. The platen configuration 700 includes a wafer head 302 disposed above a wafer 306, and having a retaining ring 304. In addition, a platen 308 is positioned below the polishing belt 310.

The platen 308 of the platen configuration 700 includes a plurality of piezoelectric elements 702 disposed below the polishing belt 310. During operation, the platen 308 is placed against the polishing pad or belt 310 that polishes the surface of the wafer 306. To promote polishing uniformity, each piezoelectric element 702 may be individually activated to apply zonal force to the polishing pad. Advantageously, the piezoelectric elements 702 improve performance in the CMP process by providing increased zonal control to the polishing belt 310. Unlike a conventional air bearing, the piezoelectric elements 702 of the embodiments of the present invention greatly reduce the amount of air needed during the CMP process.

Moreover, as with the pressurized membrane, a CMP process using the piezoelectric elements 702 of the present invention is not as sensitive to conditions as

conventional CMP processes utilizing air bearings. Unlike air bearings, the force exerted by the piezoelectric elements 702 of the present invention does not experience as great a variance as experienced by air bearings when the gap between the polishing pad 310 and the platen 308 varies. Thus, if the polishing pad 310 is pushed toward the platen 308 in one area, the force exerted on the polishing belt 310 by other piezoelectric elements 702 is not as affected as other areas would be when utilizing an air bearing.

Figure 8 is a top view of a piezoelectric element configuration 800, in accordance with an embodiment of the present invention. The piezoelectric element 702 configuration 800 includes concentric piezoelectric elements 702. Similar to the annular bladder configuration of Figure 6A, in one embodiment of the present invention, each concentric piezoelectric element 702 forms a complete circle about the center of the platen. However, to further increase zonal control during the CMP process, the length of each piezoelectric element 702 can be reduced, as shown Figure 8.

Unlike the embodiment of Figure 6A, each concentric piezoelectric element 702 of the piezoelectric element configuration 800 does not form a complete circle about the center of the platen. Each concentric piezoelectric element 702 of the piezoelectric element configuration 800 varies in size depending on a particular piezoelectric element's 702 proximity to the edge of the platen.

As mentioned previously, during a CMP process, more difficulty generally occurs within about 10-15 mm of the wafer edge. For this reason, one embodiment of the present invention increases resolution near the wafer edge by decreasing the size of the piezoelectric elements 702 near the edge of the platen. Similarly, since the center of the

wafer typically requires less resolution, the central piezoelectric elements 702 often are larger than those at the edge of the platen.

Unlike an air bearing, the embodiments of the present invention make physical contact with the polishing belt during the CMP process. As result, wear on the platen may be increased do to friction from the polishing belt. To provide additional protection from wear to the platen, a sacrificial material can be positioned between the platen and the polishing belt, as discussed next with reference to Figure 9.

Figure 9 is an illustration showing a CMP system 900, in accordance with an embodiment of the present invention. The CMP system 900 in Figure 9 is a belt-type system having an endless polishing belt 310 mounted on two drums 910, which drive the polishing belt 310 in a rotational motion as indicated by belt rotation directional arrows 906. A wafer 306 is mounted on the wafer head 302, which is rotated in direction 908. The rotating wafer 306 is then applied against the rotating polishing belt 310 with a force F to accomplish a CMP process. Some CMP processes require significant force F to be applied.

A platen 308, having piezoelectric elements 702, is provided to stabilize the polishing belt 310 and to provide a solid surface onto which to apply the wafer 306. Slurry 904 composing of an aqueous solution such as NH_4OH or DI containing dispersed abrasive particles is introduced upstream of the wafer 306. The process of scrubbing, buffing and polishing of the surface of the wafer is achieved by using an endless polishing pad glued to the polishing belt 310. Typically, the polishing pad is composed of porous or fibrous materials and lacks fix abrasives.

Disposed between platen 308 and the polishing belt 310 is a sacrificial material 914 fed roll-to-roll over the platen 308 via rollers 916. During use, the sacrificial material 914 is fed slowly over the platen 308 to provide protection from wear. In an alternative embodiment, the sacrificial material 914 is indexed as the CMP process progresses. In this manner, the sacrificial material 914 is worn, rather than the material of the platen 308. Hence, the piezoelectric elements 702 or the pressurized membrane are protected from wear caused by the friction of the rotating polishing belt 310.

Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

What is claimed is: